M&M Precision Systems Corporation

World's Most Accurate Gear-Measurement Machine

Automobile transmissions, submarine screws, and helicopter rotors can all be made quieter, smoother running, and more efficient with enhanced gear precision. By the 1980s, American gear-measurement instruments were beginning to lag behind the accuracy of gear-manufacturing technology, and the gear-measurement market shifted toward foreign-made instruments that had a higher level of accuracy. In 1994, M&M Precision Systems Corporation, in collaboration with Pennsylvania State University, submitted a proposal to the Advanced Technology Program (ATP) to develop a highly accurate gear-measurement machine. ATP awarded co-funding for a three-year project, and M&M subsequently successfully developed gear-measurement technology that was more than five times more accurate than existing U.S. gear-measurement tools. The technology was later commercialized, which increased the U.S. share of the global gear-measurement machines market to 50 percent and led to a resurgence of confidence in the accuracy of American gears.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 93-01-0191 were collected during October – December 2001.

Gear Precision Inaccuracy Harms U.S. Gear Industry

Gears have been used for centuries and are critical mechanical elements in the operation of a device that requires a transfer of motion and power to enable rotation. A mainstay of civil and military engineering, gears are in virtually all motor vehicles, aircraft, machine tools, and military combat vehicles. One of the constants of the industry is that as gears become more exact, their operation becomes smoother, quieter, and more efficient As gear-manufacturing technology became more complex, however, it was more difficult to perform gear measurements with the degree of accuracy required; thus, precision in gear manufacturing began to suffer. Partly as a result of this declining precision, the U.S. gear industry began to suffer, and German firms began taking more dominant control of the world market.

M&M Proposes World's Most Accurate Gear-Measurement Machine

No single company or organization had the capabilities or could afford the investigation required to research and identify the problems with gear-measurement machines. Therefore, M&M teamed with Pennsylvania State University to study current gear-measurement technology, to identify and eliminate weaknesses, and to create the world's most accurate gear-measurement machine.

ATP Funds Development of New Technology

Recognizing that the future of both the U.S. gear and gear-measurement industries depended on improvements, ATP funded the research and development of new gear-measurement technology.

M&M teamed with Pennsylvania State University to create the world's most accurate gear-measurement machine.

Awarded in 1994, the ATP grant provided a fresh start to the industry-an opportunity to reassess the technology, correct existing problems, and develop breakthrough technologies to enhance the precision of gear measurement. Moreover, the potential for

M&M's 3500-series machine has automatic software-driven correction, rotary axis motion, and new control technology.

far-reaching economic spillover was high. The technology would impact the nation's 350 gear and gear-related component manufacturers.

M&M Addresses Technical Issues

First, M&M engineers had to correct errors inherent in the operation of gear-measurement machines. Gear-measurement machines typically rotate the gear and compare the specimen with precise measurements taken from the appropriate gear mold. Gear-measurement machines cannot hold a specimen perfectly still, which causes errors in the final measurement. To solve this problem, M&M developed algorithms for the computer correction software that adjusts measurements for errors caused by the gear-measurement machine itself. Second, M&M tried to incorporate a linear motor into the gear-measurement machine to enable "on-the-fly" operation. Typically, gear-measurement devices set the gear in one place, take a measurement, move the gear to another fixed spot, and take another measurement. This is a time-consuming process, and M&M sought to improve the speed of gear-measurement machines by taking laser measurements as the gear rotated. Unfortunately, linear motors did not run smoothly enough to allow accurate measurements, and the gear-measurement machines resulting from the project did not have the desired on-the-fly measurement capability. In the years following the ATP project's completion, however, linear-motor technology advanced to the point where the second generation of M&M gear-measurement machines now has this capability.

ATP Project Leads to Technology and Knowledge Spillover

What began as a partnership with Pennsylvania State University evolved into a coalition of several universities. After the ATP project, M&M entered into cooperative research agreements with professors and laboratories at the University of North Carolina, Ohio State University, and the University of Toledo. Not only do these alliances generate new innovations from the academic labs, but they also train students to enter industry fully prepared to operate in, and improve upon, cutting-edge technology. According to Dean Hawk, M&M's ATP principal investigator, gear-measurement software technicians typically are not productive for the first four to six months of their tenure in the industry because they must climb a steep learning curve. Recently hired graduates of the collaborating universities, however, are capable of stepping in and being productive from day one.

Conclusion

As a result of this ATP project, M&M brought its 3500-series machine to market in 1998. The machine's most important innovations were automatic software-driven correction, rotary axis motion, and new control technology. The 3500-series machine measures spaces between gear teeth to within 0.22 uncertainty microns and provides an entire tooth profile to within 1.3 microns. This represents improvements over prior capabilities of 78 percent and 74 percent, respectively. The 3500-series machines developed through this project helped M&M to gain approximately 50 percent of the world's market share for gear-measurement machines and to increase its U.S. market share to 70 percent in the years after the project concluded. According to an M&M executive, more accurate gears enabled the U.S. automobile industry to increase the quality of its transmissions. Moreover, in the defense industry, U.S. submarines and aircraft are now the quietest in the world, in part because of their more precise gear operation.

PROJECT HIGHLIGHTS
M&M Precisions Systems Corporation

Project Title: World's Most Accurate Gear-Measurement Machine(Advanced Gear-Measurement Technologies to Achieve Submicron-Level Accuracies)

Project: To create a new generation of gear-measurement machines, which were necessary to enhance the accuracy of American-made gears, to create smoother running transmissions, and to maintain market share for gear-measurement machines within the United States.

Duration: 4/1/1994-3/31/1997
ATP Number: 93-01-0191

Funding (in thousands):

ATP Final Cost	$1,950	64%
Participant Final Cost	1,093	36%
Total	$3,043	

Accomplishments: This ATP project led to a revolution in gear-measurement technology and innovations in motor-powered transportation transmissions that were not possible before the project. By starting over and aiming to design the perfect gear-measurement machine, M&M achieved submicron-level accuracy in gear measurement. This ATP-funded project generated the following new technologies and process improvements:

- Automatic computer-controlled error-correction software
- Rotary-axis technology, enabling smoother and faster gear measurements
- New control technology, enabling a smoother, more precise gear motion during measurements

Commercialization Status: Before this ATP project, no U.S.-based company had the ability to measure gears to less than one-micron accuracy. Because this measurement inability created uncertainty about the precision of U.S.-manufactured gears, U.S. industrial customers turned to foreign companies for both gears and gear-measurement systems.

The error-correction software and control mechanisms developed by M&M during this ATP project were later commercialized into the 3500-series measurement machine. The 3500-series machine measures spaces between gear teeth to within 0.22 uncertainty microns and provides an entire tooth profile to within 1.3 microns, an improvement over previous capabilities of 78 percent and 74 percent, respectively.

The 3500-series machines helped M&M gain approximately 50 percent of the world's market share for gear-measurement machines and to increase its U.S. market share to 70 percent. Additionally, the technology had an immediate impact on the 350 gear and gear-related component manufacturers within the United States. The many improvements developed during M&M's ATP project have been incorporated extensively into automobile transmissions, submarinescrews, and helicopter rotors.

Outlook: The prototype machine developed through this ATP project continues to be the gear-measurement industry's "gold standard." The newest generation, which made its debut at gear shows in Detroit and Germany in late 2001, includes linear motors for on-the-fly measurement, in addition to the improvements already made through the ATP-funded project. These machines should continue to dominate the gear-measurement industry, allowing quieter, smoother running transmissions and gear assemblies for the foreseeable future.

Composite Performance Score: * *

Number of Employees: Seventy-seven employees at project start, 70 upon completion of status reports.

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